SEMICONDUCTOR MATERIALS FOR HIGH FREQUENCY SOLID STATE SOURCES

QUARTERLY REPORT: R920016-2

H. L. Grubin

May 1983

Defense Advanced Research Project Agency

ARPA ORDER NO; 4599

CONTRACT NO.: N00014-82-C-0697

EFFECTIVE DATE OF CONTRACT: 1 September 1982

EXPIRATION DATA OF CONTRACT: 31 August 1984

PRINCIPAL INVESTIGATOR: Dr. Harold L. Grubin

TELEPHONE NO.: (203) 659-0511

SHORT TITLE OF WORK: Semiconducting Materials

Scientific Research Associates, Inc.
P.O. Box 498
Glastonbury, CT 06033

DISTRIBUTION LIST

ADDRESSEE	DODAAD CODE
Director, Advanced Research Projects Agency 1400 Wilson Boulevard Arlington, VA 22209 ATTN: Program Management	HX1241
Scientific Officer	N00014
Administrative Contracting Officer	S0701A
Director, Naval Research Laboratory ATTN: Code 2627 Washington, DC 20375	N00173
Defense Technical Information Center Building 5 Cameron Station Alexandria, VA 22314	S47031

The purpose of this theoretical study is to provide guidelines for high frequency millimeter wave semiconductor materials selection. The theoretical methods used in the study are more general than those used in earlier studies in that transient nonequilibrium contributions are included. The results are directly applicable to submicron technology. In the study, material parameters are identified through band structure and phonon dispersion curve calculations; and transport explicitly includes electron-phonon interactions as well as impurity scattering. Carrier velocity and time dependent currents are obtained through solutions to the first three moments of the Boltzmann transport equation.

In the last reporting period a simple set of scaling rules were applied to the scattering rates of gallium arsenide. The scattering rates were doubled and halved. It was demonstrated that the response times for a scaled applied field were respectively halved and doubled. The upper frequency limit was anticipated as higher for the more rapid scattering rate.

The possibility of achieving the results predicted from linear scattering scaling is not likely to emerge from a linear scaling of the band structure parameters. This conclusion reults from a comparison of the scattering rates of InP and GaAs. Using the scaling prescription of the first SRA/DARPA report R920016-1 it was found that the scaled InP and GaAs steady state curves are similar, yet their scattering rates are different. The point here is that while the scaled velocity field curves are similar, they are arrived at with widely disparate energy separations, phonon frequencies, effective masses and deformation potential coupling coefficients. Figure 1 displays a normalized velocity electric field relation for gallium arsenide and indium phosphide. The implication of the above result is that the prescription for selecting candidate materials for high frequency applications will involve a rich set of material combinations.

During this most recent reporting period we have begun the important second phase of the DARPA study. This involves collecting the relevant band structure parameters and phonon dispersion curves are a wide variety of materials. We are approaching this task without material prejudice and are examining wide band gap materials as well as narrow band gap materials. We already have data on several of the binary III-Vs, obtained from parallel DOD sponsored programs. Ternary and quaternary mixtures of these compounds along with GaP and InSb, as well as HgCdTe are being considered.

Considerable effort has already been expended in collecting the required material parameters and it is worthwhile pointing out that in the viewpoint of this worker only a limited degree of confidence may be associated with the parameters of the subsidiary bands of some of the less frequently studied materials such as InAs and AlAs. This is particularly true when the intervalley coupling coefficients and intervalley phonon energies are considered. The situation in gallium arsenide is better only in degree. In any case the studies being performed, because of the vageries of the material constants, include parameter sensitivity calculations, where we try to get as close as possible to experimental results.

It is worthwhile to provide an indication of how the parameters of a mixed intermetallic compound semiconductor are obtained in the present program.

We start with an assumed set of parameters for the assumed known binaries: AC and BC. The material parameters of the mixed ternary $A_x B_{1-x} C$, are obtained in some cases as follows: For the effective mass

$$1/m^* = a/m_A^* + b/m_B^*$$

where a and b are the mole fractions of the binaries AC and BC respectively. The subscripts A and B also refer to the binaries AC and BC, respectively. The lattice constant of the material is

$$h = ah_A + bh_B$$

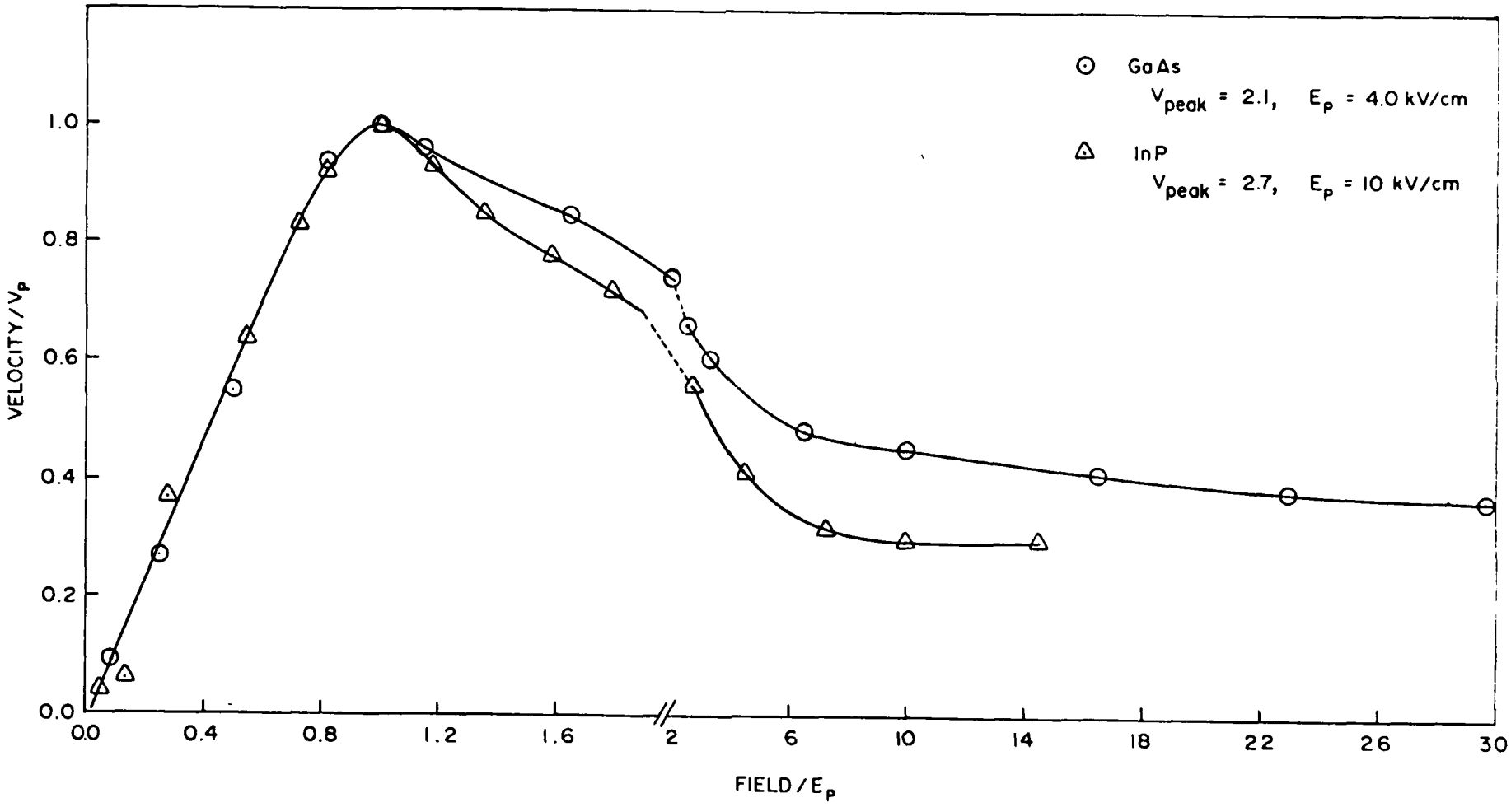
The static and high frequency dielectric constants are obtained from

$$\frac{\epsilon_{0,\infty} - 1}{\epsilon_{0,\infty} - 2} = a\left(\frac{\epsilon^A_{0,\infty} - 1}{\epsilon^A_{0,\infty} + 2}\right) + b\left(\frac{\epsilon^B_{0,\infty} - 1}{\epsilon^B_{0,\infty} + 2}\right)$$

The transverse optical frequencies are obtained from

$$\omega = \left(a\omega_{TA}^2 + b\omega_{TB}^2\right)^{1/2}$$

The deformation potential coupling coefficients are undergoing a linear extrapolation.



NORMALIZED STEADY STATE FIELD DEPENDENT CARRIER VELOCITY. SIMPLE LINEAR SCALING DOES NOT PROVIDE LINEAR VELOCITY SCALING